Infect Dis Ther (2023) 12:1265–1282
https://doi.org/10.1007/s40121-023-00793-2

REVIEW

Determinants of Meningococcal Vaccination Coverage and Adherence: A Targeted Literature Review Supporting a 16-year-old Healthcare Visit

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Received: November 22, 2022 / Accepted: March 22, 2023 / Published online: May 22, 2023

ABSTRACT

We conducted a targeted literature review to understand the determinants of meningococcal serogroups A, C, W, and Y (MenACWY) and meningococcal serogroup B (MenB) vaccination coverage and adherence to vaccination schedules in the USA, and to identify evidence to support improvement of MenACWY and MenB vaccination coverage and adherence in older adolescents. Sources published since 2011 were considered, with sources published since 2015 given preference. Out of 2355 citations screened, 47 (46 studies) were selected for inclusion. Determinants of coverage and adherence ranging from patient-level sociodemographic factors to policy-level factors were identified. Four determinants identified were associated with improved coverage and adherence: (1) well-child, preventive, or vaccination-only appointments (particularly for older adolescents); (2) provider-initiated, provider-driven vaccine recommendations; (3) provider education about meningococcal disease and vaccine recommendations; and (4) state-level school-entry immunization policies. This robust review of the literature sheds light on the continued low MenACWY and MenB vaccination coverage and adherence among older adolescents (16–-23 years of age) compared with that of younger adolescents (11–15 years of age) in the USA. The evidence supports a renewed call to action by local and national health authorities and medical organizations urging healthcare professionals to implement a healthcare visit for 16-year-olds and focus on vaccination as a key component of the visit.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40121-023-00793-2.

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PLAIN LANGUAGE SUMMARY

Certain meningococcal vaccines are recommended for young people (ages 11–23) in the USA at specific ages. We analyzed scientific studies to understand how many young people in the USA have received meningococcal vaccines and whether they received them at the recommended ages. We found that a low proportion of young people age 16 or older have received appropriate meningococcal vaccination, compared with those under age 16. We looked at reasons why this might be the case and identified actions that could be taken to increase the proportion of young people age 16 or older who receive appropriate meningococcal vaccination. Overall, the information found confirms the importance of encouraging healthcare professionals to establish routine appointments with 16-year-olds, during which they can administer recommended, age-appropriate vaccines.

Keywords: Invasive meningococcal disease; MenACWY; MenB; Adolescents; Young adults

Key Summary Points

The Advisory Committee on Immunization Practices (ACIP) recommends routine vaccination against meningococcal serogroups A, C, W, and Y (MenACWY) for 11–12-year-olds, with a booster dose at 16 years old, and recommends vaccination against meningococcal serogroup B (MenB) for 16–23-year-olds (preferably 16–18-year-olds) on the basis of shared clinical decision making.

Despite the ACIP recommendations, vaccination coverage for older adolescents (16–23 years of age) is inadequate compared with younger adolescents (11–15 years of age) in the USA.

We conducted a targeted literature review to understand the determinants of MenACWY and MenB vaccination coverage and adherence to vaccination schedules in the USA and to identify evidence to support improvement of MenACWY and MenB vaccination coverage and adherence in older adolescents.

Four determinants were associated with improved coverage and adherence: (1) well-child, preventive, or vaccination-only appointments (particularly for older adolescents); (2) provider-initiated, provider-driven vaccine recommendations; (3) provider education about meningococcal disease and vaccine recommendations; and (4) state-level school-entry immunization policies.

The evidence supports a renewed call to action by local and national health authorities and medical organizations urging healthcare professionals to implement a healthcare visit for 16-year-olds and focus on vaccination as a key component of the visit.

DIGITAL FEATURES

This article is published with digital features, including a video abstract, to facilitate understanding of the article. To view digital features for this article, go to https://doi.org/10.6084/m9.figshare.22317655

Supplementary file2. Determinants of Meningococcal Vaccination Coverage and Adherence: A Targeted Literature Review Supporting a 16-year-old Healthcare Visit (MP4 157277 KB)

INTRODUCTION

Invasive meningococcal disease (IMD) is an acute life-threatening disease that usually

manifests as bacterial meningitis, sepsis, or both. IMD has a case fatality rate of up to 50% without treatment and 5–20% even with appropriate therapy [1–4]. Up to 40% of survivors suffer long-term sequelae, which can result in physical, neurological, cognitive, behavioral, and psychological damage, including hearing loss, limb amputation, and skin scarring [5].

In 2005, the Advisory Committee on Immunization Practices (ACIP) recommended routine vaccination with a quadrivalent meningococcal conjugate vaccine for meningococcal serogroups A, C, W, and Y (MenACWY) for 11- and 12-year-old adolescents to the Centers for Disease Control and Prevention (CDC). In 2010, due to observations of waning antibody levels, and to maximize protection at the ages when adolescents are at highest risk of IMD, ACIP recommended a booster dose at 16 years old [6].

After a reduction in serogroup C, W, and Y-related cases, meningococcal serogroup B (MenB) became the predominant cause of IMD cases in the USA, accounting for > 50% of cases among 16–23-year-olds in 2018 [7]. This contributed to ACIP's initial Category B recommendation in 2015 [changed to a recommendation based on shared clinical decision making (SCDM) in 2019] for vaccination with a MenB vaccine for healthy 16–23-year-old (preferably 16–18-year-old) adolescents and young adults [8].

Despite these recommendations and the changing epidemiology, vaccination coverage for older adolescents is inadequate compared with younger adolescents in the USA. The 2020 National Immunization Survey-Teen (NIS-Teen) reported that vaccine coverage with ≥ 1 dose of a MenACWY vaccine among 13–17-year-olds reached 89.3% in 2020; however, coverage with ≥ 2 doses of a MenACWY vaccine among 17-year-olds was only 54.4%. Only 28.4% of 17-year-olds had received ≥ 1 dose of a MenB vaccine [9]. Moreover, a retrospective study found that in commercially-insured or Medicaid-insured populations from 2017 to 2020, MenB vaccine series completion was 56.7% and 44.7%, respectively [10].

The disparity in vaccination coverage between younger and older adolescents could be due to multiple factors, including the difference in vaccination platforms (vaccination practices established on the basis of recommendations). A vaccination healthcare visit at 11–12 years old is well established, and has been supported since 1996 by ACIP, the American Academy of Pediatrics (AAP), the American Academy of Family Physicians (AAFP), and the American Medical Association (AMA) [11]. However, a vaccination healthcare visit at 16–17 years old has not been consistently implemented since its recent introduction. In 2017, the CDC updated its immunization schedule for adolescents ≤ 18-years-old, adding a separate column for 16-year-olds to its table of recommendations. This column highlighted the need for a MenACWY vaccine booster dose, as well as the MenB vaccine series under SCDM [12]. The AAP, AAFP, Society for Adolescent Health and Medicine (SAHM), and four other USA-based health organizations issued a joint letter in 2019 to urge the implementation of an annual well visit and a focus on vaccinations for 16-year-olds [13].

Given the inconsistent meningococcal vaccination coverage and adherence to ACIP-recommended vaccination schedules across adolescent age groups, research is needed to further understand the challenges for vaccination coverage and adherence, their associated determinants, and similarities and differences in these challenges between the younger (11–15-year-olds) and older (16–23-year-olds) adolescent age groups.

We conducted a targeted literature review (TLR) to identify and synthesize available evidence on the determinants of MenACWY and MenB vaccination coverage and adherence. The objectives of this study were (1) to understand the challenges for MenACWY and MenB vaccination coverage and identify key evidence supporting an older adolescent (aged 16–17 years) vaccination healthcare visit to improve coverage; (2) to assess collective evidence on adherence to ACIP-recommended vaccination schedules to support healthcare providers (HCPs) and/or population-based decision makers in the USA in establishing an older

Table 1 Study Objectives

Objective	Details
1. To understand the challenges for MenACWY and MenB vaccination coverage and identify key evidence to support the improvement of MenACWY and MenB vaccination coverage via an older adolescent (aged 16–17 years) vaccination healthcare visit	Types of evidence for inclusion: (1) MenACWY and MenB vaccination coverage, (2) determinants of MenACWY or MenB vaccination coverage, (3) service delivery (missed opportunity and care provider type), (4) author-reported successes and barriers to vaccination coverage, including those from current practice and strategies/programs/interventions aiming at improving vaccination coverage, (5) vaccine impact on epidemiology (incidence) Eligible studies on both younger (aged 11–12 years, up to 15 years) and older (aged 16–23 years) adolescent groups were included. The two groups were compared and contrasted in the synthesis The potential impact of COVID-19 and equity-related issues were considered when applicable. Equity-related issues refer to social disparities including race and ethnicity, income (for which insurance type could be used as proxy), and location (rural/urban)
2. To assess collective evidence on adherence to ACIP recommendations and other USA guidelines to support USA HCPs and/or population-based decision makers in establishing an older adolescent vaccination healthcare visit, to ensure patients receive recommended adolescent vaccines [MenACWY booster, MenB, influenza, and catch-up for human papillomavirus (HPV) and Tetanus, Diphtheria, and Acellular Pertussis (Tdap) vaccines]	Types of evidence for inclusion: (1) adherence/compliance to ACIP recommendations and other USA guidelines for adolescent vaccination, on the basis of meningococcal-vaccination-related evidence; (2) determinants of adherence/compliance to ACIP recommendations and other USA guidelines for adolescent vaccination, on the basis of meningococcal-vaccination-related evidence
3. To identify key evidence, if available within the scope of the general and specific objectives previously mentioned, on additional benefits that an older adolescent well-child visit at age 16–17 can provide beyond improved vaccination coverage rates	Types of evidence for inclusion: data on ancillary health benefits resulting from a healthcare visit for a meningococcal vaccine for older adolescents. For example, well-child visits for adolescents aged 16–17 years may include screening for anxiety and depression, sexually transmitted infections, counseling for tobacco and substance use, and discussion about pregnancy and contraception

ACIP Advisory Committee on Immunization Practices, *HCPs* healthcare providers, *MenACWY* meningococcal serogroups A, C, W, and Y, *MenB* meningococcal serogroup B

adolescent vaccination healthcare visit to ensure patients receive recommended adolescent vaccines; and (3) to identify key evidence on additional benefits that an older adolescent well-child visit can provide beyond improved vaccination coverage rates. All study objectives are mapped to their corresponding types of evidence for inclusion in Table 1.

Table 2 Key barriers to increases in meningococcal vaccination coverage

Key barriers identified	Potential approaches to addressing these barriers
Patients *MenB and MenACWY vaccination:* older age at series initiation [21] *MenB vaccination:* lower household income or living in a community with a median income of less than $100,000 [23, 26]	Implementation of a platform for 16-year-olds that includes recommended vaccines and an annual well (or well-child) visit
Parents *MenB and MenACWY vaccination:* lack of vaccine awareness [29] *MenB vaccination*: concerns about side effects and uncertainty of susceptibility to MenB after receipt of a MenACWY vaccine [18]	Provider-driven recommendations to increase parental awareness and knowledge
Providers *MenB and MenACWY vaccination:* not recommending MenACWY or MenB vaccination [29] *MenB vaccination:* non-routine recommendations (Category B and SCDM) for MenB a deterrent for providers recommending the vaccine, largely due to lack of awareness about implementing the recommendations [37, 38, 44, 45]	Greater provider education and encouragement of provider-initiated and provider-driven vaccine recommendation styles, with a focus on non-pediatricians who may be less familiar with adolescent-related diseases and vaccine schedules
Healthcare service provision *MenB and MenACWY vaccination:* missing opportunities during healthcare visits [18, 22, 24, 38]	Targeted educational materials and resources for non-pediatricians and providers in rural areas; use of electronic medical records or immunization information systems and provider prompts; HCP training in immunization best practices
Policies *MenB and MenACWY vaccination:* school entry requirements for vaccinations vary by state [28, 46–49]	Encouraging policy makers to enact school entry requirements

METHODS

Databases searched included MEDLINE, including Epub Ahead-of-Print and In-process & other non-indexed citations, and Embase. In addition to searching abstracts in Embase, websites for five relevant conferences [Pediatric Academic Societies (PAS), American Academy of Pediatrics (AAP), Infectious Diseases Society of America (ID Week), National Immunization Conference (NIC), and American College Health Association (ACHA)] were hand searched for the most current year to identify studies that were yet to be indexed in Embase. Bibliographies of five recently published reviews were also examined to identify additional studies potentially missed in the database searches. Relevant evidence was also identified by undertaking keyword searches in Google and searching websites for recent reports published by government agencies and

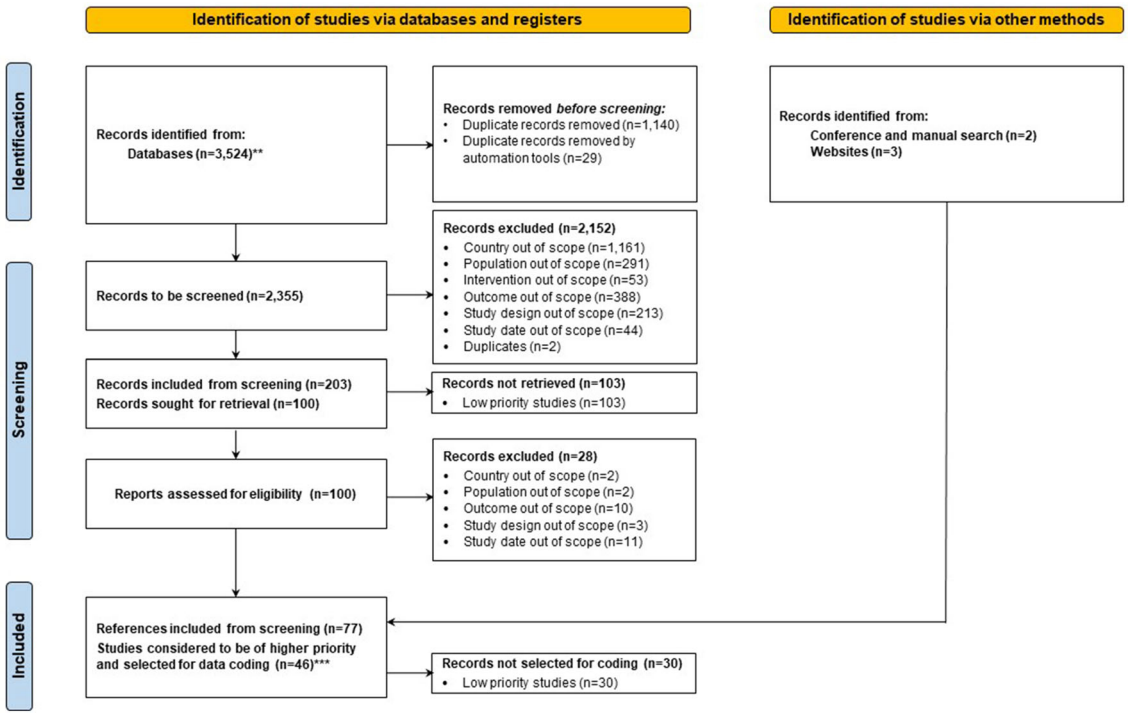

Fig. 1 Flow diagram. **Search was conducted on 7 August 2021; ***47 references corresponding to 46 unique studies, with 1 linked reference

independent associations (including CDC, ACIP, AAP, AMA, and AAFP).

Identified references were screened according to predefined population, intervention, comparator, outcome, time, and study design (PICOTS) criteria, which can be found in Table S1 in the supplementary material [14]. A search strategy using combinations of key words, indexing terms, and Boolean operators on the basis of the PICOTS criteria was developed in collaboration with an experienced medical librarian. The full search strategy can be found in Table S2 in the electronic supplementary material.

A screening algorithm (Fig. S1 in the electronic supplementary material) was used to identify the most recent, relevant, and highest quality studies for inclusion; Figs. S2 and S3 in the electronic supplementary material illustrate how studies were grouped and prioritized. The inclusion and exclusion of studies was summarized in a flow diagram (Fig. 1).

This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

RESULTS

TLR Results

A total of 2355 citations were screened, of which 203 full texts were evaluated for inclusion. In total, 100 full texts were further assessed for eligibility, of which 46 studies (reported in 47 full texts) were selected for inclusion. Study characteristics for included studies can be found in Table S3 in the electronic supplementary material. Evidence was identified for objectives 1 and 2; no evidence was identified for objective 3 (Table 1).

Vaccination Coverage

Although improvement in vaccination coverage was observed for both MenACWY and MenB vaccines over the last five years [9, 15], coverage

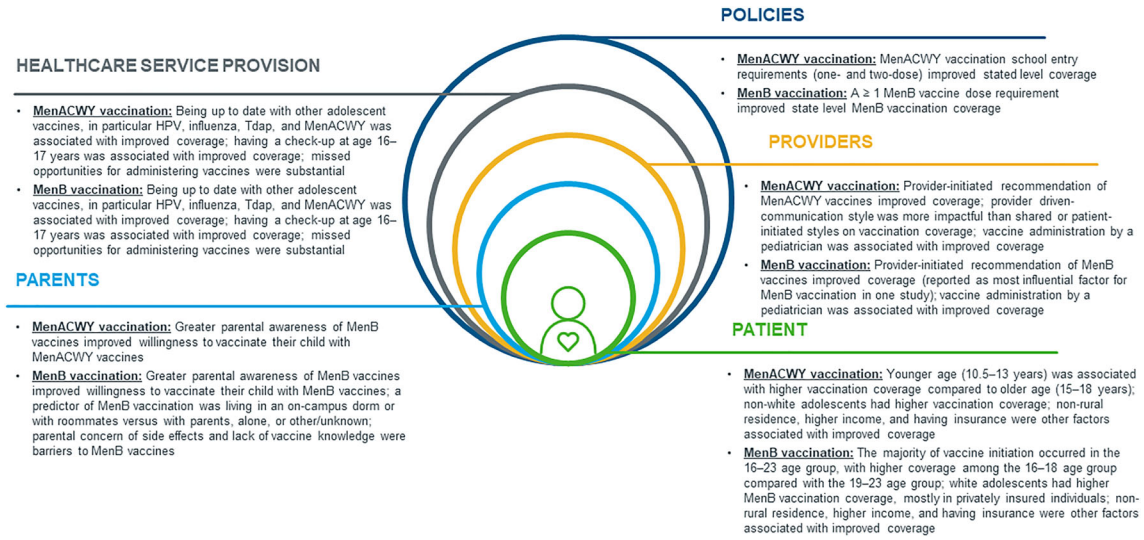

Fig. 2 Determinants associated with MenACWY and MenB coverage. *HPV* Human papillomavirus, *MenACWY* meningococcal serogroups A, C, W, and Y, *MenB* meningococcal serogroup B, *Tdap* tetanus-diphtheria-pertussis

rates varied substantially by vaccine type and age group. As expected, higher MenACWY vaccination coverage was observed for younger versus older adolescents, and overall vaccination coverage was higher for MenACWY versus MenB vaccines. Table S4 in the electronic supplementary material summarizes the evidence for MenACWY and MenB vaccination coverage.

The 2020 NIS-Teen data reported that 89.4% of 13–17-year-olds received ≥ 1 dose of a MenACWY vaccine, while only 54.4% of 17-year-olds received ≥ 2 doses. Meanwhile, the MenB vaccination initiation rate among 17-year-olds was 28.4% [9, 15]. Similar rates (20–33%) were reported for older adolescents in three other studies based on claims/medical records from 2015–2020 [16–18]. This was a substantial increase from 2016 (4.1% among 17-year-olds) [19]. The 2020 NIS-Teen data did not report the proportion of adolescents receiving ≥ 2 doses of a MenB vaccine, but 2018 NIS-Teen data reported 17.2% of 17-year-olds received ≥ 1 dose, while only 8.4% received ≥ 2 doses [20]. In two studies based on claims/medical records from 2015 to 2018, series completion was estimated to be 31–63% among those initiating a MenB vaccine series [16, 21].

Determinants Associated with Vaccination Coverage

Multiple determinants were associated with low MenACWY and MenB vaccination coverage. Figure 2 summarizes the findings, with direct patient-level factors at the center, followed by more distal factors (parents, providers, healthcare system administrators, and policies).

Patient-Level Sociodemographic Factors

Sociodemographic factors, particularly age, race, residence, income, and insurance status, were identified as influential factors associated with meningococcal vaccination coverage.

For MenACWY vaccination, an analysis of two large claims datasets (including 1,313,323 adolescents) in 2011 to 2016 reported that older age (15.5–18 years old) was associated with reduced MenACWY vaccination coverage versus younger age (10.5–13 years old) [22]. Coverage for older adolescents versus younger adolescents was 31.8% versus 59.3% ($p < 0.001$) among Medicaid patients and 48.9% versus 71.7% ($p < 0.001$) among privately insured patients, indicating challenges for vaccination coverage in the older adolescent population [22].

For MenB vaccination, in a claims analysis of 2,501,188 adolescents and young adults (10–25-year-olds) in 2017, receipt of ≥ 1 dose of the MenB vaccine was 2.5% and 1.6% in the 16–18- and 19–23-year-old age groups, respectively, and lowest in the youngest (10–15-year-olds) and oldest (24–25-year-olds) age groups (both 0.2%). The difference across age groups was statistically significant ($p < 0.01$) [23]. Notably, this study reported lower rates than other identified studies, possibly because it captured data only 18 months after ACIP's initial Category B (now SCDM) recommendation.

Better MenACWY vaccination coverage was found in non-white versus white adolescents on the basis of two studies. One study analyzed data of 3807 17-year-olds in the 2017 NIS-Teen survey [24], and the other study analyzed Medicaid claims data of 516,684 10.5–18-year-olds [22]. By contrast, the highest MenB vaccination coverage was among adolescents who were white and mostly privately insured [16, 23, 25, 26]. The evidence was inconclusive for Asian and Hispanic groups due to the lack of consistency in reporting.

Residing in a non-rural area [i.e., metropolitan statistical area (MSA), MSA principal city, or urban/inner city] versus a rural area (defined by the census as any area not classified as urban) [27] was associated with higher MenACWY and MenB vaccination coverage [9, 15, 21–23]. For MenACWY vaccination, coverage in non-rural areas was reported in the range of 51.1–90.3% versus 34.2–85.7% in rural areas [9, 15, 22]. For MenB vaccination, one study reported that coverage in non-rural areas was in the range of 0.9–1.5% versus 0.6% in rural areas, although this study reported lower rates than other identified studies, possibly because it captured data only 18 months after ACIP's initial Category B (now SCDM) recommendation [23].

Income and insurance status were associated with MenB vaccination coverage on the basis of six studies. No studies testing these relationships were identified for MenACWY vaccination. Lower household income or living in a community with a median income of less than $20,000 was associated with lower MenB vaccination coverage [23, 26]. Having some form of insurance, private or Medicaid, was associated with improved MenB vaccination coverage [16, 20, 21, 28]. Sex had no significant impact on MenACWY and MenB vaccination coverage on the basis of three studies [21, 22, 25].

Impact of Parents

Three survey studies reported on parental factors impacting their child's receipt of MenACWY and/or MenB [18, 25, 29]. In a survey of 445 parents with children attending high school in Minnesota during the 2017–2018 academic year, lack of vaccine awareness was reported as a top reason for their child not being vaccinated against MenACWY or MenB (40.0% and 31.5%, respectively). Although 75.5% of patients considered themselves aware of meningococcal vaccines in general, 68.8% and 80.0–82.0% of parents were unaware of the common brand names for MenACWY and MenB vaccines, respectively [29]. Parents who were aware of at least one MenB vaccine were more willing to vaccinate their child with a MenB vaccine or MenACWY vaccine and to complete the vaccination series versus parents who were unaware. Parental awareness of at least one MenACWY vaccine brand name was not associated with willingness to vaccinate their child [29]. For MenB vaccination, a survey of 170 parents of 16–17-year-olds in Florida identified parental concerns about side effects and uncertainty of susceptibility to MenB after receipt of a MenACWY vaccine as the most common barriers to vaccination [18].

Living arrangement was also reported as potentially influential in a national study that surveyed 529 HCPs and conducted chart reviews of 2832 16–23-year-olds [25]. Adolescents who received a MenACWY vaccine were more likely to live with their parents (78.2%) versus in an on-campus dorm with or without roommates [25]. For MenB vaccination, living in an on-campus dorm or with roommates versus living with parents, alone, or other was a predictor of higher MenB vaccination coverage [25].

Provider Factors

Ten studies reported provider-related factors influencing MenACWY and/or MenB

vaccination coverage [16, 21, 22, 25, 28–33]. Four studies reported that provider-initiated recommendations for MenACWY and MenB vaccines were associated with improved coverage [29–32]. A 2013 NIS-Teen survey reported that vaccination coverage of 13–17-year-olds was 88.1% for those whose parents recalled a provider recommendation versus 73.1% for those whose parents did not [31]. For MenB vaccination, a survey of 619 US parents of 16–19-year-olds reported an HCP recommendation as the most influential factor in predicting MenB vaccination status [28]. Parents who received a recommendation from a provider were 4.8 times more likely to vaccinate their child and 5.7 times more likely to have an adolescent already vaccinated versus parents who did not receive a recommendation [30]. Finally, a survey of 445 parents of children attending high school in Minnesota reported that a top reason their child had not received a MenACWY or MenB vaccine was because their HCP did not recommend the vaccine (33.9% and 32.7%, respectively) [29].

One study examined the influence of patient–provider communication style on MenACWY vaccination coverage and found that an efficient provider-driven style (recommendation initiated by the provider) was associated with higher coverage rates (82%) versus shared style (77%) and patient-driven informed style (68%) [32].

Provider type was also found to be an influential factor. MenACWY [22, 33] and MenB coverage [25] and MenB vaccine series completion [21] were higher when vaccines were ordered by a pediatrician versus other HCP types. Other provider-related factors included years in practice [16] and patient age when the vaccine is recommended [33].

Healthcare Service Provision: Encounters and Missed Opportunities

Ten studies reported factors influencing meningococcal vaccination coverage related to healthcare resource use [9, 15, 19–25, 28]. Being up to date with other adolescent vaccinations was associated with improved MenACWY and/or MenB vaccination coverage [20–25, 34]. An analysis of 3807 17-year-olds in the 2017 NIS-Teen survey reported that MenACWY vaccination coverage was 51.4% overall, but was significantly higher among adolescents who received a vaccination for influenza (68.3%), human papillomavirus (HPV; 63.7%), or tetanus-diphtheria-pertussis (Tdap; 58.0%) [24]. Similarly, a claims analysis of 2,501,188 10–25-year-olds found that the strongest predictor of MenB vaccination was prior receipt of MenACWY or HPV vaccines [23]. Adolescents with prior MenACWY or HPV vaccination were 36.1 and 5.1 times more likely to have received a MenB vaccine, with coverage of 9.8% and 5.1%, respectively in 2017 [23]. Improved MenB vaccine series completion was associated with receipt of MenACWY and influenza vaccines, while recipients of other catch-up vaccines had a decreased likelihood of series completion on the basis of an analysis of 78,740 16–23-year-olds [21].

Three studies reported that having a check-up at 16–17 years old or a well-child or preventive visit was associated with improved meningococcal vaccination coverage [19, 22, 24]. An analysis of 3807 17-year-olds in the 2017 NIS-Teen survey found that the odds of MenACWY vaccination were 3.1 times higher if the adolescent had a check-up at 16 or 17 years old [24]. Similarly, the odds of MenB vaccination were 1.8 times higher if the adolescent had a check-up at 16 or 17 years old on the basis of an analysis of NIS-Teen data on 17-year-olds pooled across 2016 to 2018 [19].

Despite evidence that more encounters with the healthcare system improve vaccination coverage, particularly receiving other adolescent vaccines and a well-child or preventive visit at 16–17 years old, substantial missed opportunities were reported. For MenACWY vaccination, missed opportunities were observed for both younger and older adolescents, but more were observed for the older age group. On the basis of commercial claims data from 2011 to 2016, approximately 31.9% of older adolescents (15.5–18-years-old) and 21.6% of younger adolescents (10.5–13-years-old) had additional vaccination opportunities with at least one potential missed opportunity for MenACWY vaccination [22]. A missed opportunity was defined as a preventive care, well-

child, or vaccine-only visit occurring in the outpatient office setting during which the individual was age-eligible for a MenACWY vaccine but did not receive a dose [22]. Similar results were also observed with 2017 NIS-Teen data for older adolescents, where it was estimated that 45.9% of adolescents received either Tdap (4.5%), HPV (21.3%), or influenza (32.3%) vaccines at 16 or 17 years old, of whom 28.6% were not up to date on MenACWY vaccination (defined as either having received two doses by 17 years old or one dose at 16 or 17 years old per ACIP recommendation) and had missed opportunities [24].

One study further evaluated the determinants for missed opportunities for MenACWY vaccination. Receiving care from a non-pediatric HCP and living in a rural setting were associated with increased likelihood of having ≥ 1 potential missed opportunity for older adolescents. Total number of non-MenACWY vaccines received and provider type were the most important variables contributing to the gap between the younger and older age groups [22]. A 2018 survey of 170 parents in Florida estimated that only 31% of parents recalled receiving a physician recommendation for MenB vaccination. On the basis of state immunization records and parental reports, only 9–22% of adolescents had initiated a MenB vaccine series, suggesting most 16–17-year-olds had missed opportunities for MenB vaccination [18].

Policies: State Mandates and School Policies

Two studies reported on the influence of state mandates and school policies on meningococcal vaccination coverage [24, 35]. As of 2019, 31 states required the MenACWY primary dose for school and college entry, of which 16 also required the booster dose at 16 years, and only one state required a MenB vaccination [35]. One study that classified NIS-Teen data according to state school entry immunization polices found that median state-level MenACWY vaccination coverage was higher in states with a one-dose school entry requirement (54.1%) and two-dose requirement (63.6%) versus no requirement (41.5%, $p = 0.001$) [24]. Similar findings were reported in a study that descriptively evaluated the relationship between state requirements and MenACWY (85% for ≥ one dose, 44% for ≥ two doses) and MenB coverage (14.5% for ≥ one dose of multidose series) [35].

Vaccination Schedule Adherence

In 2005 ACIP recommended that all 11–12-year-olds receive one dose of a MenACWY vaccine, and in 2010 recommended a booster dose at 16 years old. A study using NIS-Teen data from 2011 to 2016 estimated that only 12.1% of

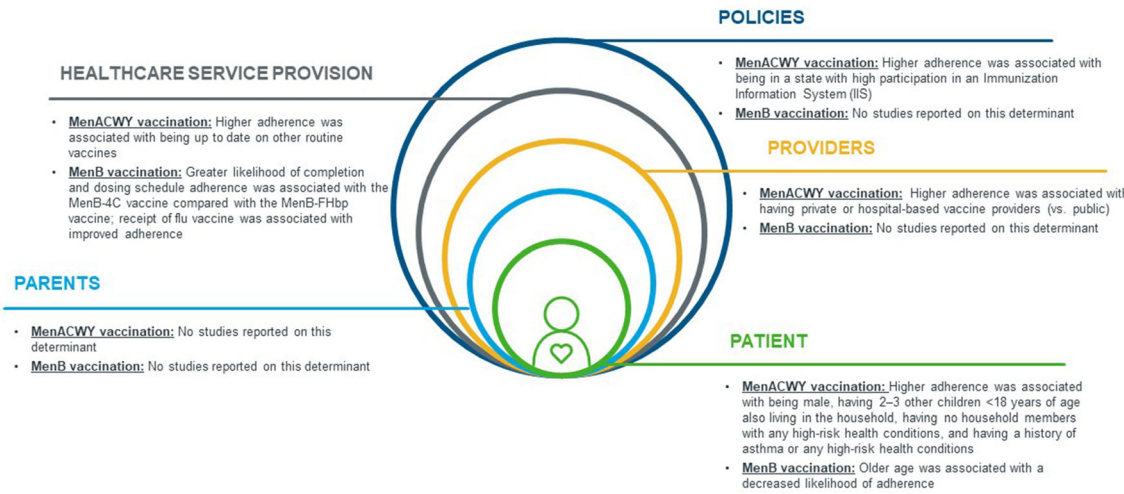

Fig. 3 Determinants associated with MenACWY and MenB ACIP-recommended vaccination schedule adherence. *MenACWY* meningococcal serogroups A, C, W, and Y, *MenB* meningococcal serogroup B

MenACWY-vaccinated 17-year-olds received their vaccines on this schedule, although the adherence to the ACIP-recommended vaccination schedule (reported as "compliance" in the study) increased from 0.8% in 2011 to 23.9% in 2016 [36]. This low adherence could be driven by the low rates observed among older adolescents, as shown in an analysis using commercial claims data from 2011 to 2016 [22]. Among younger adolescents (10.5–13-year-olds) who received a MenACWY vaccine, 91.9% received the vaccine at 11–12 years old, adhering to the ACIP-recommended age for the primary dose. However, for older adolescents (15.5–18-year-olds) who received a MenACWY vaccine dose, only 35.8% received the vaccine at the ACIP-recommended age of 16 years old [22]. **Table S5** in the electronic supplementary material summarizes the evidence for adherence to the MenACWY and MenB ACIP-recommended vaccination schedules.

The adherence criteria are different for MenB vaccination since the vaccine is recommended for healthy older adolescents under SCDM. The ACIP-recommended vaccination schedule also requires completion of a two-dose or three-dose series, depending on the brand of MenB vaccine. One study using claims data from 2015 to 2018 reported that most of the vaccinated older adolescents initiated their MenB vaccine series at the preferred age of 16–18 years old (77.3–79.3% in the commercial population, 98.2–98.3% in the Medicaid population) [21]. However, challenges were observed for series completion and adherence to the ACIP-recommended vaccination schedule of subsequent doses. For MenB-4C, which has a recommended dosing schedule of two doses $\geq$ 1 month apart, only 63% and 49% of the initiators in the commercial and Medicaid populations, respectively, completed the two-dose series within 15 months, with 62% and 48%, respectively, of the initiators adhering to the dosing schedule [21]. For MenB-FHbp, which has a recommended dosing schedule of two doses at 0 and 6 months or three doses at 0, 1–2, and 6 months, only 52% and 31% of the initiators in the commercial and Medicaid populations, respectively, completed the two- or three-dose series within 15 months, and only 18% and 8%, respectively, of the initiators adhered to the dosing schedule [21]. The time to completion of the vaccine series was shorter, and adherence to the ACIP-recommended vaccination schedule higher, for MenB-4C versus MenB-FHbp, inherent to their different dosing schedules [21].

Determinants Associated with Vaccination Schedule Adherence

Two studies reported on determinants associated with ACIP-recommended vaccination schedule adherence [21, 36]. Figure 3 summarizes the findings, with direct patient-level factors at the center, followed by more distal factors (parents, providers, healthcare system administrators, and policies).

For MenACWY vaccination, adherence to the ACIP-recommended vaccination schedule varied significantly by state of residence. On the basis of NIS-Teen data from 2011 to 2016, while the national adherence rate among 17-year-olds was 12.1%, the state-specific adherence rate ranged from 3.1% (South Dakota) to 26.2% (North Dakota). Higher likelihood of adherence was found to be associated with a series of determinants, including being male, having 2–3 other children < 18-years-old also living in the household, having no household members with any high-risk health conditions, having a history of asthma or any high-risk health conditions, having private or hospital-based vaccine providers (versus public), being up to date on other routine vaccines, and being in a state with high participation in an Immunization Information Systems (IIS) [36].

For MenB vaccination, age of initiation was a key determinant for series completion and ACIP-recommended vaccination schedule adherence—each additional year of age at series initiation was associated with a decreased likelihood of series completion and adherence for both MenB-4C and MenB-FHbp [21]. Another influential factor was vaccine type—higher likelihood of series completion and ACIP-recommended vaccination schedule adherence was associated with MenB-4C versus MenB-FHbp. Receipt of influenza vaccination in the post-index period was also consistently a

significant factor associated with increased likelihood of completing and adhering to the vaccine series. Other factors found to be associated with MenB vaccine series completion and/or ACIP-recommended vaccination schedule adherence were sex, geographic region, race, residence density (rural versus urban), month of initiation, type of encounter, provider type, and presence of high-risk condition. However, the significance and direction were not always consistent in different insurance cohorts [21].

Provider Adherence to Guidelines

On the basis of HCP surveys, vaccination patterns were largely different between MenACWY and MenB vaccines. In general, provider adherence to the ACIP-recommended vaccination schedule was high for MenACWY vaccines, but relatively low for MenB vaccines.

For MenACWY, a survey evaluating vaccine recommendations by providers in 2013, almost 8 years after the initial MenACWY ACIP recommendation, found that 84% of 91 surveyed clinics had a policy of recommending MenACWY vaccination to all patients 11–12 years old [33]. For MenB, a national survey of 660 HCPs in 2016, a year after the initial MenB ACIP Category B (now SCDM) recommendation, found that 58% of pediatricians and 50% of family physicians recommended a MenB vaccine for 16–18-years-olds. By comparison, 81% of pediatricians and 56% of family physicians recommended a MenB vaccine for children with an increased risk of meningococcal disease for whom a routine recommendation is in place [37]. Another national survey of 529 HCPs in 2017 found that 77% of HCPs correctly interpreted the ACIP recommendation for MenACWY vaccination, responding that they would recommend a MenACWY vaccine dose for all members of the eligible age groups [25]. However, only 7% of HCPs responded that they would recommend a MenB vaccine on the basis of an individualized clinical decision, consistent with ACIP's Category B recommendation (now SCDM) [25].

Among surveyed HCPs, higher rates of vaccine recommendation and discussion were observed in pre-college versus routine well visits for 16–18-year-olds [37]. A multivariable analysis based on national survey data found HCP characteristics associated with a higher likelihood of recommending or ordering MenB vaccination included male sex, being a pediatrician, treating a higher number of 16–23-year-olds, having more years in the practice, and having a higher number of patients knowledgeable about the difference between MenB and MenACWY vaccines [25]. Awareness of MenB, such as outbreaks or incidence of disease, vaccine effectiveness, and safety, was also associated with a higher likelihood of providers recommending a MenB vaccine, while the non-routine Category B (now SCDM) recommendation was a deterrent [37, 38].

DISCUSSION

This targeted review of the literature sheds light on the continued low meningococcal vaccination coverage and adherence rates among older adolescents in the USA, along with multiple missed opportunities to offer vaccination against meningococcal disease. Identified determinants significantly associated with vaccination coverage improvements are actionable by HCPs, healthcare system administrators, and policy makers, including: (1) well-child, preventive, or vaccination-only appointments (particularly for older adolescents); (2) provider-initiated, provider-driven vaccine recommendations; (3) provider education about meningococcal disease and vaccine recommendations; and (4) state-level school-entry immunization policies.

Call to Action for a Vaccination Platform for 16-Year-Olds

A call to action urging healthcare professionals to institute a platform for 16-year-olds that includes recommended vaccines and an annual well (or well-child) visit was announced in a 2019 letter signed by leadership at seven major medical and professional associations, but the coronavirus disease 2019 (COVID-19) pandemic hindered implementation efforts [13, 39, 40].

The platform for 16-year-olds would advance multiple determinants associated with improving vaccination coverage and adherence to ACIP-recommended vaccination schedules and address several sociodemographic barriers identified in this review that are often not considered actionable. It would help to standardize practice for quality purposes and promote equity in vaccination access across factors such as race, ethnicity, level of income, and geography (rural and non-rural areas), where the evidence shows disparities in rates of vaccination coverage. Ideally, all 16-year-olds would receive the recommended, appropriate vaccinations at the same age, and also receive other age-appropriate preventive services [13]. A visit for 16-year-olds would serve as an opportunity to administer both a MenACWY vaccine (the booster dose recommended at age 16) and possibly a MenB vaccine (recommended under SCDM at age 16).

A platform for 16-year-olds may be even more relevant today because of disruptions to the delivery of routine services caused by the COVID-19 pandemic, which has resulted in decreased routine vaccinations [41]. Other service delivery models have emerged from these disruptions, such as greater reliance on telemedicine and pharmacies for adolescent vaccine consultation [42]. A platform for 16-year-olds would be an opportunity to efficiently provide multiple age-appropriate services in a single visit while adolescents are still under parental care, and set the foundation for an optimally immunized adulthood and continuous health-seeking behaviors.

Provider Factors Impacting Vaccination

The evidence also supports a patient–provider communication style that is both provider-initiated and provider-driven for meningococcal vaccination [32]. For both MenACWY and MenB vaccination, not receiving a provider recommendation was a top reason why parents did not have their child immunized [29].

Lower provider adherence to ACIP-recommended vaccination schedules for MenB as compared with MenACWY may be due to the duration of time needed for the medical community to gain knowledge, change perceptions, and broadly implement a recommendation, and to the different strengths of ACIP recommendations for the two types of vaccines. Currently, MenACWY vaccines fall under routine vaccination recommendation in which the default decision is to provide the vaccine, whereas MenB vaccines fall under a SCDM vaccination recommendation, in which there is no default decision and the decision is left to be made between the patient and provider [43].

Therefore, under SCDM, improving adolescent vaccine uptake relies even more heavily on efficient, provider-driven communication styles. In one study, a provider-driven communication style was associated with higher rates of meningococcal vaccine uptake [32]. Meanwhile, for MenACWY and MenB vaccination, not receiving a provider recommendation was one of the top reasons why parents did not have their child immunized [29]. While SCDM presents an important opportunity for providers to ensure patients and parents feel well equipped with the information to make MenB vaccination decisions, consistent implementation of SCDM recommendations remains a key challenge [26, 37, 38, 44]. In national surveys, only 7–24% of HCPs correctly interpreted ACIP's SCDM recommendation [25, 45]. One national survey found that the SCDM guidance was a reason to order a MenB vaccine in 37% of HCPs; however, it was also a reason not to order the vaccine in 38% of HCPs [44]. Another survey reported that 48% of pediatricians and 42% of family physicians were deterred by this non-routine recommendation [38]. Providers were also noted not to initiate discussions on MenB vaccines when they did not intend to recommend it, reflecting their own decisions, without involving parents or patients in the discussion, suggesting a lack of awareness of the "shared" aspect of SCDM of the role of the provider [37].

Related to embracing a provider-initiated and provider-driven communication style, there is a need for both greater provider education and patient education materials to help empower and facilitate provider discussions with patients and parents, particularly for non-pediatricians who may be less familiar with

adolescent-related diseases and vaccine schedules.

Systems Factors Impacting Vaccination

Finally, discrepancies in meningococcal vaccination coverage were observed between states with school entry requirements for grades 6–12 and college, suggesting that policy makers should consider adopting school entry requirements to realize impactful and long-term health benefits for their state. School entry requirements have long been an important component of immunization programs in the USA, and reluctance to embrace policies varies state by state [35]. Srivastava et al. provides a summary of MenB and MenACWY vaccination requirements by state, and more detailed information on school vaccination requirements by state has also been published by the CDC [35, 46]. Immunize.org, formerly the Immunization Action Coalition, has also published comprehensive vaccine recommendations and mandates by state, as well as for college and university entry [47–49].

Key Barriers to Further Increases in Coverage and Adherence

While the focus of the review was to identify the determinants associated with improved MenB and MenACWY vaccination coverage and adherence, understanding the key barriers to these improvements may help to guide future approaches. Table 2 summarizes the key barriers to increases in MenACWY and MenB vaccination coverage and adherence identified, and describes potential approaches to addressing these barriers on the basis of the reviewed literature.

Limitations

Unlike a systematic literature review (SLR) that aims to include all eligible studies, this TLR prioritized studies that were newer (published since 2015, when ACIP recommended the MenB vaccine series), relevant to the population and objectives, had a larger sample size, had a published manuscript, and were seminal/well cited. To minimize bias, a thorough search and screening of titles and abstracts was conducted following procedures typical of a SLR. Selection criteria was then applied during full-text review to narrow down the most pertinent studies. In addition, while most (31) selected studies were conducted using a national sample, some were conducted in specific counties or states and therefore not generalizable to the broader US population. A limitation of the current literature was that while race differences in coverage by vaccine type have been reported, the reasons for these differences have not been investigated, and thus could not be reported in this review. Another possible limitation of the current literature was that coverage levels specifically for Medically Underserved Areas (MUAs) were not identified in the review, and thus could also not be reported. Further research on vaccine coverage levels should target MUAs to better understand and guide future interventions in these areas.

Finally, the initial study intended to extract and synthesize information on successful strategies and vaccination strategies to improve coverage. However, only a few interventions were identified and were not included in this manuscript because most were reported in one-off studies and there is no indication that the studies would be replicable across diverse settings.

CONCLUSIONS

Through careful evaluation of the current evidence, we provide an updated and comprehensive overview of the determinants of MenACWY and MenB vaccination coverage and adherence. We highlight the need for scheduling well-child, preventive, or vaccination-only appointments (particularly for older adolescents), encouraging effective provider communication styles (including provider-initiated and provider-driven vaccine recommendations), educating providers about meningococcal disease and vaccine recommendations, and state-level school-entry immunization policies to improve MenACWY and MenB vaccination coverage and adherence. Implementing these measures could have implications not only at a

public health level regarding meningococcal disease prevention among adolescents, but also at the practice level by providing opportunities for adolescents to receive other age-appropriate care. Ultimately, this study supports a renewed call to action by national health authorities and medical organizations urging healthcare professionals to implement a healthcare visit at 16-year-olds and focus on vaccination as a key component of the visit.

ACKNOWLEDGEMENTS

Funding. This study was sponsored by GlaxoSmithKline Biologicals SA (Study identifier HE-VEO-000015). GlaxoSmithKline Biologicals SA was involved in all stages of the conduct and analysis of the study and covered all costs associated with the development and the publishing of the present manuscript, including the rapid service fee.

Medical Writing and/or Editorial Assistance. Support for third-party writing assistance for this article, provided by Hannah L. Fox, PhD, Costello Medical, US and Katie Hamilton, Costello Medical, US was funded by GSK in accordance with Good Publication Practice (GPP3) guidelines (http://www.ismpp.org/gpp3).

Author contributions. Oscar Herrera-Restrepo: substantial contributions to study conception and design, analysis and interpretation of the data, critically revising the article for important intellectual content, and final approval of the article to be published; Yuting Kuang: substantial contributions to analysis and interpretation of the data, critically revising the article for important intellectual content, and final approval of the article to be published; John D'Angelo: substantial contributions to study conception and design, analysis and interpretation of the data, critically revising the article for important intellectual content, and final approval of the article to be published; Rafik Bekkat-Berkani: substantial contributions to study conception and design, analysis and interpretation of the data, critically revising the article for important intellectual content, and final approval of the article to be published; Diana E. Clements: substantial contributions to study conception and design, analysis and interpretation of the data, critically revising the article for important intellectual content, and final approval of the article to be published; and Jennifer Uyei: substantial contributions to study conception and design, analysis and interpretation of the data, critically revising the article for important intellectual content, and final approval of the article to be published.

Prior Presentation. Some of the data presented in this manuscript were presented at the AAFP Family Medicine Experience September 20–23, 2022 in Washington, DC.

Disclosures. Oscar Herrera-Restrepo, John D'Angelo, Diana E. Clements, and Rafik Bekkat-Berkani are employees of and hold shares in GSK. Yuting Kuang and Jennifer Uyei are employees of IQVIA, which was paid by GSK to conduct this study.

Compliance With Ethics Guidelines. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

Data Availability. Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

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